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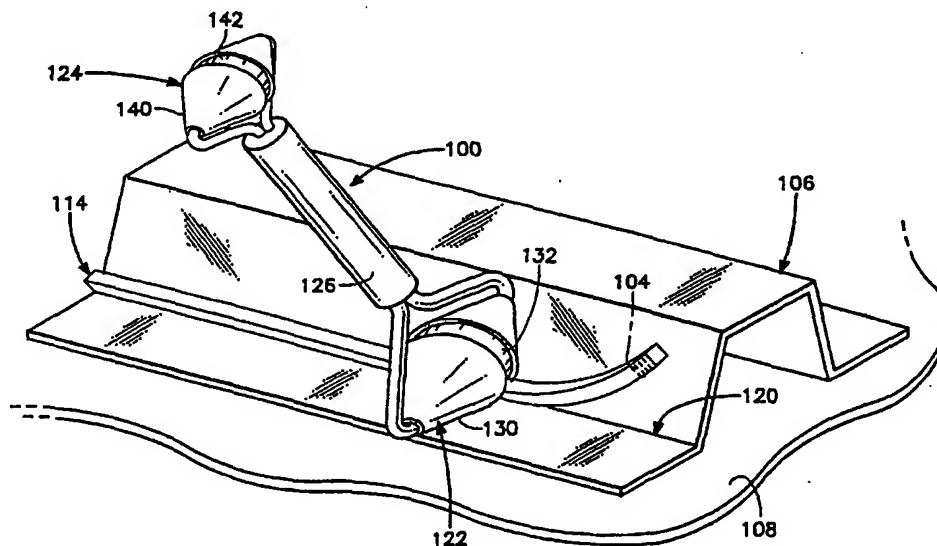
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(54) Title: Z-FIBER PINNING TOOL



(57) Abstract

A method and tool (100) for installing Z-pins (104) in order to reinforce a joint between carbon fiber structures. The tool utilizes a handle (126) and first (122) and second heads (124) in order to drive the Z-pins into the joint in two steps. In step 1, the Z-pins are driven in partially, while in step 2 they are driven in fully. The Z-pins are supported and oriented in a compressible material (114). Each head of the tool is designed to constrain and compress the material containing the Z-pins in addition to conforming to the profile of the joint. In this way, this tool allows for the Z-pins to be inserted in a precise location on the joint.

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Z-FIBER PINNING TOOL

Background of the Invention

5 1. Field of the Invention.

The present invention relates in general to fiber pinning tools and in particular to a fiber pinning tool for structurally applying fiber stiffeners to a material.

10 2. Related Art.

Many structural composites, such as structural composite airframes, usually consist of multiple stiffeners. The stiffeners supply rigidity and stiffness that is required under certain flight load conditions. One typical stiffener is a mechanical fastener, such as a hat stiffener. Hat stiffeners, named for their shape, are typically applied to aerospace structural composite components via their skin.

One process for fabricating hat stiffeners is to co-cure the hat to the skin of the structural composite material concurrently with the curing of the structural composite material itself. Another process for fabricating hat stiffeners is to secondarily mechanically bolt and/or adhesively bond the stiffener to the skin. However, in either case, the failure mode for both processes occurs at the inner hat to skin surface.

In order to resolve this problem, z-pinning is used. Z-pinning refers to applying reinforcing fibers in the same direction (or at a canted angle, such as 45°) that the composite fibers of the structural composite material reside in. In contrast, the X and Y direction is in-plane with the fibers of the structural composite material. The stiffeners are usually pinned in the Z-direction to the skin with large pinning fibers, such as boron fibers. The pinning fibers are typically imbedded in a material, such as Teflon. This technique has been

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found to increase the mechanical properties of the stiffener to skin interface.

In one method (hereinafter referred to as "multiple fiber pressing"), the Z-pinning process typically consists of first softening the composite stiffener and skin with heat and then driving plural fibers through the skin using a press. Since numerous fibers are forced into the skin at once, pressure needed to insert the plural fibers covering large areas at once must be done hydraulically. In another method (hereinafter referred to as "individual fiber insertion"), the Z-pinning process typically consists of forcing individual fibers through the skin one at a time. The fibers are forced into the skin with an ultrasonic device, which uses high frequency for vibrating the fiber and eventually forcing it into the skin.

Both processes are lacking. For instance, the multiple fiber pressing method is very costly and expensive since custom tooling for the press is required to match and properly interface the specific pinning fibers with the composite material. In addition, it would be impossible to z-pin fibers in a 45° angle at the inner hat to skin interface with this process. The individual fiber insertion method is very time consuming, tedious, requires many man hours (approximately 2 hours per in² of inserted fibers), and is not suitable for a production process. As such, these pressing methods are inefficient and not ideal for large scale components and manufacturing tooling.

Therefore, what is needed is a fiber pinning tool for efficiently structurally applying fiber stiffeners to a material. What is also needed is an inexpensive process for efficiently applying fiber stiffeners to a material. Whatever the merits of the above mentioned systems and methods, they do not achieve the benefits of the present invention.

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Summary of the Invention

To overcome the limitations in the prior art described above, and to overcome other limitations that will become apparent upon reading and understanding the present specification, the present invention is embodied in an apparatus and method for structurally applying fiber stiffeners to a material.

Specifically, the present invention is embodied in a tool for inserting a plurality of fibers embedded in a transfer material through a hat stiffener and into a substrate. For inserting the fibers into an angled corner, the tool includes a first head, a second head, and a handle. The first head is defined by a roller having first beveled edges and a center cutout. The first beveled edges conform to the angled corner of the hat stiffener and the cutout corresponds to the thickness of the transfer material.

The second head is located at a distal end from the first head and is defined by a roller having second beveled edges and a center groove. The second beveled edges conform to the angled corner of the hat stiffener and the groove corresponds to a thickness associated with guiding the tool along the corner of the hat stiffener. The center handle is coupled between the first head and second head for gripping. The first head is adapted to initially drive the fibers embedded in the transfer material through the hat stiffener and into the substrate. The second head is adapted to finally secure the fibers within the hat stiffener and the substrate. For inserting the fibers into a flat surface, all of the beveled edges are flat edges or is a shim guide.

One feature of the present invention is the dual roller for driving and securing a plurality of fibers into a substrate. One advantage of the present invention is that the insertion of the fibers can be accomplished efficiently and inexpensively.

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The foregoing and still further features and advantages of the present invention as well as a more complete understanding thereof will be made apparent from a study of the following detailed description of the invention in connection with the accompanying drawings and appended claims.

Brief Description of the Drawings

Referring now to the drawings in which like reference numbers represent corresponding parts throughout:

FIG. 1 is a perspective view of a tool of the present invention for angled insertion of fibers through a stiffener and into a substrate;

FIG. 2 is a perspective view of a tool of the present invention for flat insertion of fibers through a stiffener and into a substrate;

FIG. 3 is a partial cross-sectional view of the tool of FIG. 1; and

FIG. 4 is a partial cross-sectional view of the tool of FIG 2.

Detailed Description of the Preferred Embodiment

In the following description of the preferred embodiment, reference is made to the accompanying drawings which form a part hereof, and in which is shown by way of illustration a specific embodiment in which the invention may be practiced. It is to be understood that other embodiments may be utilized and structural changes may be made without departing from the scope of the present invention.

Overview:

FIG. 1 is a perspective view of a tool of the present invention for insertion of fibers through a stiffener and into a substrate. The tool 100 of the present invention is for structurally inserting fibers

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104 through a stiffener 106 and into a substrate 108. The stiffener 106 is preferably a mechanical fastener, such as a hat stiffener, but can be any suitable stiffener for providing required rigidity and stiffness to the substrate 108 under certain load conditions. The substrate 108 is preferably a composite substrate, such as a skin of an airframe. The fibers 104 can be any suitable fibers capable of adequately securing the stiffener to the substrate, such as commercially available boron fibers. The fibers 104 are typically embedded in a transfer material 114, such as Teflon, for allowing multiple insertion and easy transfer of the fibers.

15 Components:

Referring to FIG. 1, the tool of the present invention for angled insertion of fibers through a stiffener and into a substrate is shown. For inserting the fibers 104 into an angled corner 120 of the hat stiffener 106, the tool 100 includes a first head 122, a second head 124, and a handle 126. The first head 122 can be a roller having first beveled edges 130 and a center cutout 132. The first beveled edges 130 conform to the angled corner 120 of the hat stiffener 106 and the center cutout 132 corresponds to the thickness of the transfer material 114.

The second head 124 is located at an opposite end from the first head 122 and can be a roller having second beveled edges 140 and a center groove 142. The second beveled edges 140 conform to the angled corner 120 of the hat stiffener 106 and the center groove 142 corresponds to a thickness associated with guiding the tool 100 along the angled corner 120 of the hat stiffener 106. The center handle 126 is coupled between the first head 122 and the second head 124 for easy gripping by a user.

FIG. 2 is a perspective view of a tool of the present invention for flat insertion of fibers through a

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stiffener and into a substrate. For inserting the fibers 104 into a flat surface 220 of the hat stiffener 106, the tool 200 includes a first head 222, a second head 224, and a handle 226. The first head 222 can be a roller having first flat edges 230 and a center cutout 232. The first flat edges 230 conform to the flat surface 220 of the hat stiffener 106 and the center cutout 232 corresponds to the thickness of the transfer material 114.

10 The second head 224 is located at an opposite end from the first head 222 and can be a roller having second flat edges 240 and a center groove 242. The second flat edges 240 conform to the flat surface 220 of the hat stiffener 106 and the center groove 242 corresponds to a thickness associated with guiding the tool 200 along the flat surface 220 of the hat stiffener 106. The center handle 226 is coupled between the first head 222 and the second head 224 for easy gripping by a user.

20 Operation:

FIG. 3 is a partial cross-sectional view of the tool of FIG. 1. Referring to FIG. 1 along with FIG. 3, first, the transfer material 114 is located on the area of the stiffener 106 that the fibers 104 are to be inserted through. In the case of the hat stiffener 106 of FIG. 1, the fibers 104 are to be inserted through the area designated by the angled corner 120 and into substrate 108. Second, the first head 122 is placed over the transfer material 114 so that the transfer material 114 resides within the center cutout 132 of the first head 122.

35 Third, the handle 126 is gripped by a user and the tool 100 is traversed back and forth along the angled corner 120 several times until the fibers 104 are driven through the hat stiffener 106 and into the substrate 108 so that the transfer material 114 is flush with the hat stiffener 106. Fourth, the transfer material 114 is

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removed and the tool 100 is flipped so that the second head 124 is placed within the angled corner 120 so that the inserted fiber area resides below the center groove 142 of the second head 122. Next, the handle 126 is gripped by the user and the tool 100 is traversed back and forth along the angled corner 120 several times until the fibers 104 are secured within the hat stiffener 106 and the substrate 108. It should be noted that heat can be used to aid in inserting and securing the fibers 104 within the hat stiffener 106 and the substrate 108.

FIG. 4 is a partial cross-sectional view of the tool of FIG. 2. Referring to FIG. 2 along with FIG. 4, first, the transfer material 114 is located on the area of the stiffener 106 that the fibers 104 are to be inserted through. In the case of the hat stiffener 106 of FIG. 2, the fibers 104 are to be inserted through the area designated by the flat surface 220 and into substrate 108. Second, the first head 222 is placed over the transfer material 114 so that the transfer material 114 resides within the center cutout 232 of the first head 222.

Third, the handle 226 is gripped by a user and the tool 200 is traversed back and forth along the flat surface 220 several times until the fibers 104 are driven through the hat stiffener 106 and into the substrate 108 so that the transfer material 114 is flush with the hat stiffener 106. Fourth, the transfer material 114 is removed and the tool 200 is flipped so that the second head 224 is placed on the flat surface 220 so that the inserted fiber area resides below the center groove 242 of the second head 222. Next, the handle 226 is gripped by the user and the tool 200 is traversed back and forth along the angled corner 220 several times until the fibers 104 are secured within the hat stiffener 106 and the substrate 108. It should be noted that heat can be used to aid in inserting and securing the fibers 104 within the hat stiffener 106 and the substrate 108.

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In summary, the first head 122 of FIG. 1 and the first head 222 of FIG. 2 are adapted to initially insert the fibers 104 embedded in the transfer material 114 through respective areas 120, 220 of the hat stiffener 106, and into the substrate 108. In contrast, the second head 124 of FIG. 1 and the second head 224 of FIG. 2 are adapted to finally secure the fibers 104 within respective areas 120, 220 of the hat stiffener 106 and the substrate 108. This z-pinning action increases the mechanical strength of the stiffener. Also, the tools 100, 200 are easily manually operated, which significantly eliminates expensive tooling required for automatic presses, while allowing manually guided placement of the fibers for improved fiber insertion accuracy. Further, the fiber volume can be easily increased through reapplication of fibers in the stiffener.

The foregoing description of the preferred embodiment of the invention has been presented for the purposes of illustration and description. Additional z-pinning applications, such as z-pinning fibers directly into substrates can be performed with the tool of the present invention. As such, the specification is not intended to be exhaustive or to limit the invention to the precise form disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not by this detailed description, but rather by the claims appended hereto.

WHAT IS CLAIMED:

1. A tool for inserting a plurality of fibers embedded in a transfer material with a predetermined thickness through a surface of a hat stiffener and into
5 a substrate comprising:

a first head defined by a roller having a center cutout, wherein said cutout corresponds to the thickness of the transfer material;

10 a second head located at a distal end from said first head and defined by a roller having a center groove, wherein said center groove corresponds to a thickness associated with a predetermined guidance factor for guiding the tool along the substrate; and

15 a center handle coupled between said first head and said second head;

wherein said first head is adapted to initially drive the fibers embedded in the transfer material through the hat stiffener and into the substrate and said second head is adapted to finally secure the
20 fibers within the hat stiffener and the substrate.

2. The tool as set forth in claim 1, wherein the surface of the hat stiffener is a flat surface.

3. The tool as set forth in claim 2, wherein said first head is defined by a roller having first flat edges
25 conforming to said flat surface of the hat stiffener.

4. The tool as set forth in claim 3, wherein said second head is defined by a roller having second flat edges conforming to said flat surface of the hat stiffener.

30 5. The tool as set forth in claim 1, wherein the surface of the hat stiffener is an angled surface.

6. The tool as set forth in claim 5, wherein said first head is defined by a roller having first beveled edges conforming to said angled surface of the hat
35 stiffener.

7. The tool as set forth in claim 6, wherein said second head is defined by a roller having second beveled

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edges conforming to said angled surface of the hat stiffener.

8. A tool for inserting a plurality of fibers embedded in a transfer material with a predetermined thickness through a surface of a hat stiffener and into a substrate comprising:

10 a first head defined by a roller having a first set of edges and a center cutout, wherein said first set of edges angularly conform to the surface of the hat stiffener and said cutout corresponds to the thickness of the transfer material;

15 a second head located at a distal end from said first head and defined by a roller having a second set of edges and a center groove, wherein said second set of edges angularly conform to the surface of the hat stiffener and said center groove corresponds to a thickness associated with guiding the tool along the substrate; and

20 a center handle coupled between said first head and said second head;

25 wherein said first head is adapted to initially drive the fibers embedded in the transfer material through the hat stiffener and into the substrate and said second head is adapted to finally secure the fibers within the hat stiffener and the substrate.

9. The tool as set forth in claim 8, wherein:

the surface of the hat stiffener is a flat surface;

30 said first head is defined by a roller having first flat edges conforming to said flat surface of the hat stiffener; and

said a second head is defined by a roller having second flat edges conforming to said flat surface of the hat stiffener.

35 10. The tool as set forth in claim 8, wherein:

the surface of the hat stiffener is an angled surface;

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said first head is defined by a roller having first beveled edges conforming to said angled surface of the hat stiffener; and

5 said a second head is defined by a roller having second beveled edges conforming to said angled surface of the hat stiffener.

11. A method for inserting a plurality of fibers embedded in a transfer material with a predetermined thickness through a surface of a hat stiffener and into
10 a substrate comprising the steps of:

initially driving the fibers embedded in the transfer material through the hat stiffener into the substrate by rolling a first head having a center cutout corresponding to the thickness of the transfer material until the fibers are flush with
15 the substrate; and

securing the fibers within the hat stiffener and the substrate by rolling a second head having a center groove corresponding to a thickness
20 associated with guiding the tool along the substrate until the fibers are suitably secured within the substrate.

12. The method as set forth in claim 11, wherein the surface of the hat stiffener is a flat surface.

25 13. The method as set forth in claim 12, wherein said first head is defined by a roller having first flat edges conforming to said flat surface of the hat stiffener.

14. The method as set forth in claim 13, wherein
30 said second head is defined by a roller having second flat edges conforming to said flat surface of the hat stiffener.

15. The tool as set forth in claim 11, wherein the surface of the hat stiffener is an angled surface.

35 16. The tool as set forth in claim 11, wherein said first head is defined by a roller having first beveled

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edges conforming to said angled surface of the hat stiffener.

17. The tool as set forth in claim 11, wherein said second head is defined by a roller having second beveled
5 edges conforming to said angled surface of the hat stiffener.

AMENDED CLAIMS

[received by the International Bureau on 11 June 1999 (11.06.99);
original claims 1-17 cancelled; new claims 18-25 added (2 pages)]

WHAT IS CLAIMED:

1. Canceled.
2. Canceled.
3. Canceled.
- 5 4. Canceled.
5. Canceled.
6. Canceled.
7. Canceled.
8. Canceled.
- 10 9. Canceled.
10. Canceled.
11. Canceled.
12. Canceled.
13. Canceled.
- 15 14. Canceled.
15. Canceled.
16. Canceled.
17. Canceled.
18. (New) A Z-pinning tool for facilitating the
20 insertion of a multiplicity of pinning fibers embedded in
a transfer material of a prescribed width and thickness
through a stiffener member and into a substrate to secure
the stiffener member to the substrate, the tool
comprising:
25 a handle having opposed first and second ends;
a first head rotatably connected to the first
end of the handle and including first end portions
which are separated by an annular first groove
having a width which exceeds the width of the
30 transfer material and a depth which is less than the
thickness of the transfer material, the first head
being adapted to facilitate the proper location of
the pinning fibers within the stiffener member when
passed over the transfer material; and
35 a second head rotatably connected to the second
end of the handle and including second end portions
which are separated by an annular second groove

having a depth which is less than the depth of the first groove, the second head being adapted to facilitate the insertion of the pinning fibers into the substrate when passed thereover.

5 19. (New) The tool of Claim 18 wherein the first end portions of the first head and the second end portions of the second head each define a generally cylindrical outer surface.

10 20. (New) The tool of Claim 19 wherein:
the diameters of the outer surfaces of the first end portions of the first head are substantially equal to each other; and
the diameters of the outer surfaces of the second end portions of the second head are
15 substantially equal to each other.

21. (New) The tool of Claim 20 wherein the diameters of the outer surfaces of the first end portions of the first head exceed the diameters of the outer surfaces of the second end portions of the second head.

20 22. (New) The tool of Claim 18 wherein:
the first end portions of the first head are of substantially equal lengths; and
the second end portions of the second head are of substantially equal lengths.

25 23. (New) The tool of Claim 22 wherein the widths of the first end portions of the first head exceed the widths of the second end portions of the second head.

24. (New) The tool of Claim 18 wherein the first end portions of the first head and the second end
30 portions of the second head each define a beveled outer surface.

25. (New) The tool of Claim 24 wherein the outer surfaces of the first end portions of the first head and the second end portions of the second end are each of a
35 gradually decreasing diameter as they extend away from respective ones of the first and second grooves.

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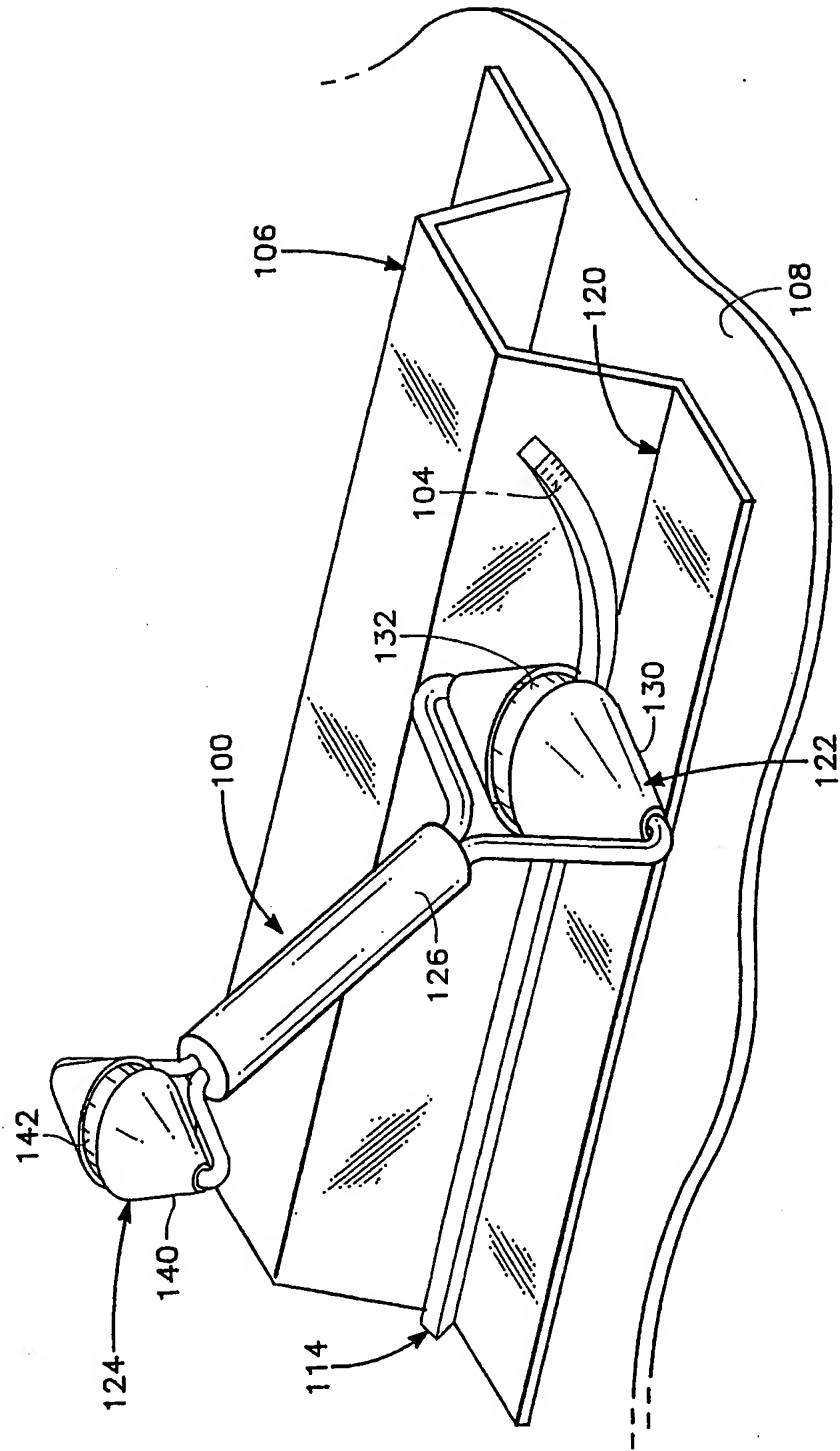


FIG. 1

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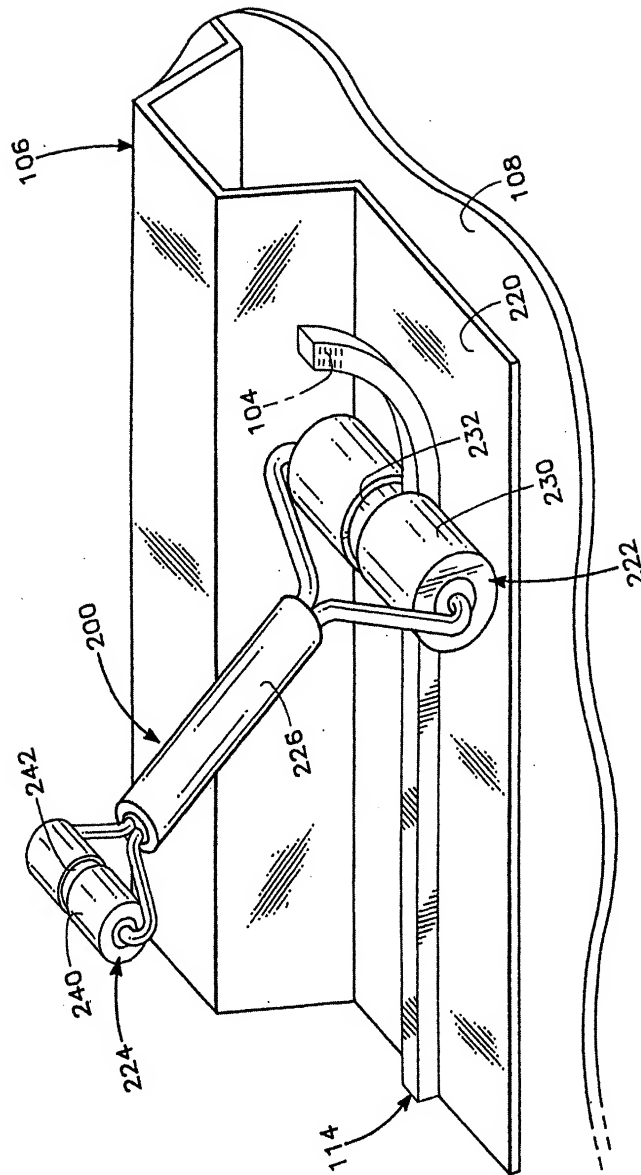


FIG. 2

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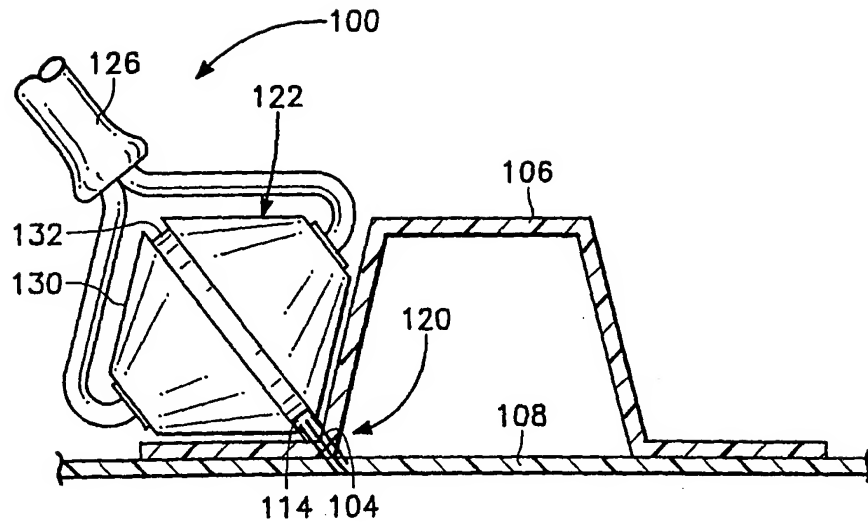


FIG. 3

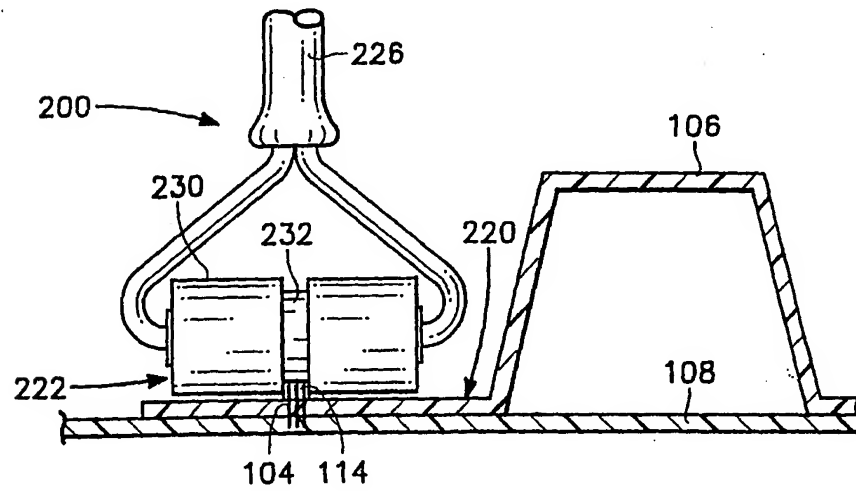


FIG. 4

INTERNATIONAL SEARCH REPORT

 International application No.
 PCT/US99/07724

A. CLASSIFICATION OF SUBJECT MATTER IPC(6) :B29C 43/20; DO3D 41/00; B32B 5/07 US CL :29/432, 432.1, 235, 798, 451; 428/119; 227/119, 142 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) U.S. : 29/432, 432.1, 235, 798, 451; 428/119; 227/119, 142 Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) APS		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 5,466,506 A (FREITAS et al.) 14 November 1995, See entire document.	1-17
Y	US 148,643 A (ANNADALE, Jr.) 17 March 1874, See entire document	1-17
Y	US 3,157,135 A (FETROW et al.) 17 November 1964, See entire document.	1-17
Y	US 4,197,624 A (LASS) 15 April 1980, See entire document.	6, 7, 10, 16 and 17
<input type="checkbox"/> Further documents are listed in the continuation of Box C. <input type="checkbox"/> See patent family annex.		
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Date of the actual completion of the international search 17 MAY 1999		Date of mailing of the international search report 28 May 1999 (18.05.99)
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231 Facsimile No. (703) 305-3230		Authorized officer TOM HUGHES Telephone No. (703) 308-1806 <i>Sheila Venev</i> <i>Paralegal Specialist</i> <i>Technology Center 3700</i>